Response to Referee #2

General comments

> The paper presents a climatology analysis focused on LLJ in the North Sea based on biascorrected ERA5 and NORA3 data. The topic is important for meteorology and wind energy, and the methods appear sound. However, minor revisions are advised to improve the reliability and repeatability of the results.

We appreciate and agree with your comprehensive and constructive comments. We have thoroughly revised our manuscript and believe that the new version has improved significantly. Here are the changes that we made in accordance with your comments:

> The quantile mapping and bias correction are applied regardless of season, wind direction, and other parameters that may influence the model performance, This should be discussed thoroughly in Section 2, since correcting for overall bias may mask cancellation of errors of opposite sign happening in different data clusters.

We completely agree with this assessment. We have added a dedicated discussion acknowledging this limitation in Section 2.3 (Lines [175-181]). We explain that while a conditional bias correction would be ideal, dividing our relatively short (approx. 1-year) LiDAR dataset into seasonal or directional bins resulted in sample sizes too small to build robust distributions, leading to severe overfitting during quantile mapping. The global correction is therefore utilized as a robust baseline for this specific climatological application.

> The use of a logarithmic profile in the stable conditions where the jet develops needs more justification. It should be clarified whether the addition of the jet profile reduces the need for a stability correction, for instance.

Thank you for pointing this out. We have added a concise justification in Section 2.2 (Lines [133-136]). We clarify that in our decomposition method, the log profile primarily serves as a background component that increases with height monotonically, rather than a strict physical representation of the boundary layer. The empirical jet profile provides the mathematical flexibility to account for stability-induced deviations.

> A map of the FINO site with the nearby coastline and wind farms should be added at the beginning of Section 2.

This is an excellent suggestion. We have added a map showing the FINO1 platform, coastlines, and the precise footprints of the active and planned offshore wind farms (using EMODnet data). This has been added as the new Figure 1 in Section 2.1.

> The flow can be improved. For instance, do results in Section 3.1 refer to model data before or after the bias correction? Describing all the methods in section 2 and the results in section 3, although customary, in this case may lead to confusion. A schematic

> of the workflow may help as well. There should be a detailed description of how the bias correction is practically implemented. Are the 5 parameters of the log-jet function adjusted so that the fitted profiles follow the observations more closely? Is there an intervention on the full model output U, V, W, T, etc? Is the model rerun with different settings? Please clarify.

We thank the reviewer for highlighting these areas for improvement. To address the flow and clarify the methodology:

- We created a comprehensive workflow schematic (**new Figure 3**) mapping out the calibration and reconstruction phases and explained it in detail (Lines [158-164]).
- We thoroughly revised the Bias Correction subsection (Section 2.3) to explicitly state the practical implementation: we do not rerun the ERA5 model or intervene in the 3D model outputs. As the reviewer surmised, we strictly extract the 5 log-jet parameters, adjust them via quantile mapping to follow the observations, and analytically reconstruct the profiles (Lines [165-174]).
- We revised Section 3.1 by adding an introductory transition to clarify that this section evaluates the raw model data before any bias correction is applied. (Lines [198-203])

Specific comments

> L 65: Please provide more details on the experimental dataset, specifically the temporal averaging, the type of scan used for profiling, the lidar model, and the data availability during the campaign.

We have updated Section 2.1 (Lines [67-70]) to include the specific instrument details. The campaign utilized a WindCube 100S and employed a Doppler Beam Swinging (DBS) scan strategy. The data were natively recorded and subsequently aggregated to hourly averages to ensure temporal alignment with the NORA3 hindcast dataset. Data availability remained robust throughout the duration of the campaign.

> Fig. 1: Please clarify whether the time is UTC or local.

We have updated the caption for this figure (now Figure 2) to clarify that all times are in UTC. We also added this clarification to the temporal pattern plots (Figure 10).

> Fig. 3: What is upper-case U* on the x axis?

It was a typo, however, we changed the variable to U_m in this revised version (now Fig. 5)

> L 155: Please describe the score used in the K-means (silhouette?) and provide a reference for the elbow method.

We have updated Section 2.4 (Lines [183-190]) to specify that we used the Within-Cluster Sum of Squares (WCSS, or inertia) for the elbow method. A standard citation for the elbow method (Thorndike, 1953)has been added.

> L 166: Why would the agreement between ERA5 and NORA3 be surprising if the latter uses the former as a boundary condition? Please expand.

We have expanded the text in Section 3.1 (Lines [203-209]) to clarify our reasoning. While NORA3 relies on ERA5 for synoptic boundary conditions, it is a non-hydrostatic model with a 3 km spatial resolution explicitly designed to dynamically downscale ERA5. We expected this high-resolution downscaling to provide noticeable "added value" by better resolving the sharp vertical gradients characteristic of boundary-layer LLJs. The fact that NORA3 failed to outperform the 31 km ERA5—yielding the same systematic underestimation—is what we found surprising.

> L 243: missing capitalization.

This typo has been corrected.